Saskatchewan
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AGRICULTURE DEVELOPMENT FUND

FINAL REPORT

20000259

APPLICATION OF LIQUID SWINE MANURE FROM AN INTENSIVE LIVESTOCK OPERATION TO A HYBRID POPLAR PLANTATION

Funded by: The Agriculture Development Fund

May, 2006

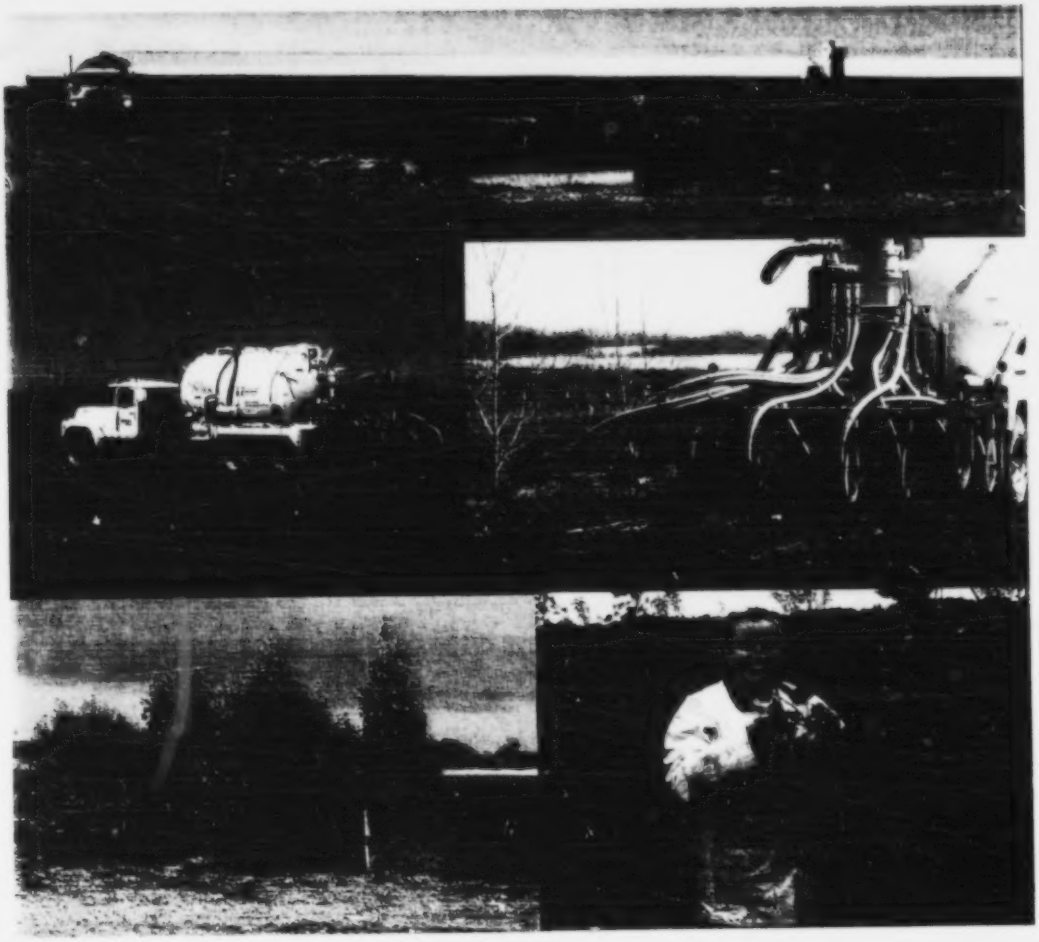
Prepared by: Agriculture and Agri-Food Canada

2007-04642/

Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

Agriculture, Food and Rural Revitalization

Application of sewage effluent from an intensive livestock operation to hybrid poplar plantings.



ADF Project# 20000259
Final Report

PAMI

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Acknowledgement of partners:

This project was funded by the Saskatchewan Agriculture Development Fund.

Gordon Hultgreen and Wayne Stock of the Prairie Agricultural Machinery Institute (PAMI) (P.O. Box 1150, Hwy #5 West, Humboldt, SK. S0K 2A0) advised in the design of the Preeceville alley-cropping system, adapted their tanker truck's delivery system and applied the swine effluent at Preeceville.

Rosaasen Farms of Preeceville, SK provided the land for the alley-cropping system, as well as important in-kind support in managing the site and valuable feedback throughout the project.

Big Sky Farms permitted us to use the effluent from their Preeceville swine production facility.

Louise Corriveau of Weyerhaeuser Canada permitted us use of the poplar plantation at the Weyerhaeuser Seed Orchard at Henribourg, SK and gave valuable in-kind support.

Application of sewage effluent from an intensive livestock operation to hybrid poplar plantings.

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Citation: Kort, J. and Stefner, C. 2006. Application of sewage effluent from an intensive livestock operation to hybrid poplar plantings. Final Report: Saskatchewan Agriculture Development Fund Project# 20000259. Saskatchewan Agriculture and Food, Regina, SK. 27 pp.

Abstract

This project had two components related to the use of poplar trees for the uptake of nitrogen and the responses of the poplar trees to added nitrogen in Saskatchewan. These consisted of 1) a new poplar planting designed in an alley-cropping configuration to allow for access by effluent application equipment and 2) the testing of nitrogen response by older trees in a 1998, closely-spaced block plantation. In the new planting at Preeceville, SK, the trees were planted in rows with 10 m alleys and included replicated plots of four different poplar clones that were selected at the Agriculture and Agri-Food Canada PFRA Shelterbelt Centre for use in shelterbelts. The 10 m alleys were wide enough for easy access by the Prairie Agricultural Machinery Institute (PAMI) effluent tanker truck. In this planting, the trees were well-established by the fall of 2005 and, after four growing seasons, had reached an average height of 2.6 m and an average diameter at breast height (DBH) of 2.2 cm. Although the trees were successfully established and effluent was applied in both 2004 and 2005, no growth response to added nitrogen was seen in these trees. This was attributed to the low nitrogen requirements of the trees at their young age and the adequate nitrogen levels that existed in the soil at the time of establishment. There were clonal growth differences detected but these were independent of soil nitrogen levels. In the older plantation at the Weyerhaeuser Seed Orchard at Henribourg, SK, which attained an average height of 7.4 m by the fall of 2005 and an average DBH of 8.7 cm, different levels of ammonium nitrate granular fertilizer which was broadcast-applied did not have a significant effect on the total height or DBH of Walker poplar trees, although there was an indication that annual height increase in the last three years was greater at the higher nitrogen application rates and higher leaf nitrogen concentrations were related to greater height growth. The lack of significant overall growth in this plantation could similarly be attributed to the young age of the trees and the adequate levels of soil nitrogen, although other factors that affected the growth of the trees over the study period could have overshadowed any nutrient level effects since, in addition to variability in the soil, drought and winter dieback occurred during the study. The results from these two tests did not suggest levels of nitrogen application required by the trees. On the contrary, they suggested that poplar trees planted in sites with adequate soil nitrogen require little applied nitrogen in their early years.

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1 Introduction and Objectives

The disposal of swine effluent from intensive operations is both a challenge and an opportunity. The effluent slurry contains nitrogen which can be used to fertilize agricultural land but the low concentration of nitrogen makes long-distance transport uneconomical. At the same time, swine producers need to avoid negative environmental impacts such as leaching of nitrogen into groundwater and runoff into water bodies. Swine effluent can be sustainably applied to land to productively use the manure nutrients while minimizing water pollution hazards.

Hybrid poplars are a potential target crop for the safe application of swine effluent because of their fast growth and reprtedly high rates of water and nutrient use. Hybrid poplars have been used in many environmental applications around the world and have been found to use large quantities of nitrogen. Examples of the quantities cited are 86 kg/ha/yr for 5-year-old trees in Minnesota (Hansen and Baker 1979), 112 kg/ha/yr for a plantation in Wisconsin (Hansen and Tolsted 1985), 276 kg/ha/yr in Washington (Heilman and Stettler 1986) and as much as 400 kg/ha/yr in a municipal wastewater study at Seattle, Washington (Breuer *et al.* 1977). Stanturf *et al.* (2001) recommended that, for commercial poplar plantations, nitrogen fertilization should begin only after canopy closure and be applied at low rates annually or biennially at rates of between 50 and 100 kg/ha/year. Strand (1986) reported early height and diameter response to added nitrogen in hybrid poplars in the Columbia River Basin in eastern Oregon.

The fast poplar growth reported in Oregon and Washington are likely not achievable in Saskatchewan so that nitrogen needs are likely less here. In Saskatchewan, the growth rate of hybrid poplar is limited by the growing season, soil moisture, light and temperature. However, the northern and eastern regions of agricultural Saskatchewan are suitable for the growth of adapted clones (Schroeder 1999). In suitable sites where adequate water supply is available, hybrid poplars are the fastest-growing trees and therefore likely have the greatest nitrogen requirement. Hybrid poplar wood can be used in pulp, oriented strandboard and lumber or other value-added wood products and has been suggested as an alternative crop (Saskatchewan Forest Centre 2005).

Because of these considerations, this project was undertaken to develop a hybrid poplar plantation to which swine effluent could be conveniently applied and which would use the nitrogen for increased growth. The effect of nitrogen application on the growth of trees was studied in this project as well as the changes in soil nitrogen levels. In the project, the logistics of using swine effluent on hybrid poplar trees was also studied.

The objectives of this project were to:

1) Evaluate the environmental benefits of a poplar plantation to which swine manure is applied.
2) Assess the logistics of alternative application systems by developing an ILO effluent / agroforestry system including the establishment of a 3.0 hectare poplar plantation designed especially for the purpose.

The project consisted of two distinct parts: a swine effluent – agroforestry system that was developed at Preeceville, SK and the addition of nitrogen fertilizer to existing poplar trees at Henribourg, SK.

At Preeceville, a poplar planting was established in an alley-cropping configuration on which swine effluent was applied in the third and fourth years after establishment. The effluent was applied by tank from the Prairie Agricultural Machinery Institute's (PAMI) metered truck/tank system. The planting was designed to be compatible with this effluent application method. A total area of 3.0 hectares (7.4 acres) was used and two planting designs, a twin-row design and a single-row design, were established. Effluent was put on four different poplar clones at three different rates plus a non-fertilized control.

At Henribourg, granular fertilizer was applied at three rates plus an unfertilized control to Walker poplar trees that had been planted in a plantation with trees planted in 1998 in a 2.4 m X 2.4 m grid.

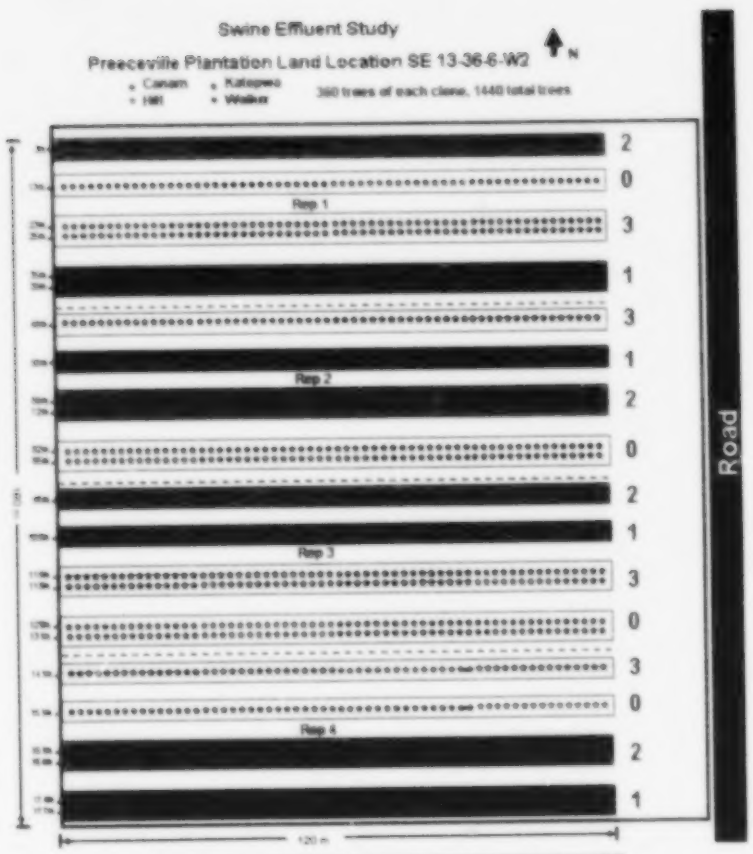
2 Preeceville

2.1 Materials and Methods

2.1.1 Site

In spring, 2002, 1440 rooted poplar cuttings were established on 3.0 hectares northwest of Preeceville, SK. The site was a slightly undulating glacial till with several low spots. The lowest spot was in the northeast corner and many of the trees that were planted there did not survive or grew very poorly. The soil texture was a loam in which the clay content in the plots varied from 29% to 40% with an average of 33% in the upper 30 cm and from 33% to 42% with an average of 38% for the 30-60 cm depth. Silt varied from 23% to 34% in the upper 30 cm and from 20% to 36% in the lower 30 cm.

The trees were arranged in rows with 10 m alleys between them for machinery access for swine effluent application (Figure 1). The plantation was established across the road from an Intensive Livestock Operation (ILO) where the effluent was obtained. Four poplar clones were planted in single rows and in double rows. In both the single-row and double-row designs, the trees were planted 2 m apart within the rows. In the double-row design, the tree rows were 3 m apart. The rows were subdivided according to Figure 1, into four different poplar clones – Walker, Canam, Hill and Katepwa. Despite all of these clones being well-adapted under Saskatchewan climatic conditions, they differ in form and growth rate. Walker poplar is a fast-growing female clone which has been distributed for shelterbelts for over forty years. It has an upright, columnar form and has been identified by the wood-processing industry as having potential for lumber, OSB or pulp. Canam poplar is an upright female clone that was selected especially for its ability to withstand drought but, under good growing conditions, its growth rate is less than that of the Walker poplar. Hill poplar is a broad-crowned female clone. Katepwa poplar is an upright male clone with a narrow crown which was recently named and was previously designated 'OPW-180H-86'. All of these clones were expected to do well at Preeceville.



Application of swine effluent 2004 and 2005		
Number and colour codes		Application rates (2004 & 2005)
0	White	No effluent
1		22500 l/ha
2		45000 l/ha
3	Yellow	90000 l/ha

Figure 1. Layout of the Preeceville poplar planting (102°43 "5

2.1.2 PAMI manure truck

The Prairie Agricultural Machinery Institute (PAMI) truck was originally designed for injection application of swine effluent into the soil at a depth of 11 cm. However, since poplar roots generally grow near the surface of the soil, the truck was adapted by adding an adjustable boom to the rear of the tool bar to allow for the surface application, thus preventing damage to the tree roots. The boom system evenly distributed the effluent over a 3.5 m area and was offset 1.5 m outside of the truck's width on the driver's side to allow for application at the base of the trees (Figure 2).

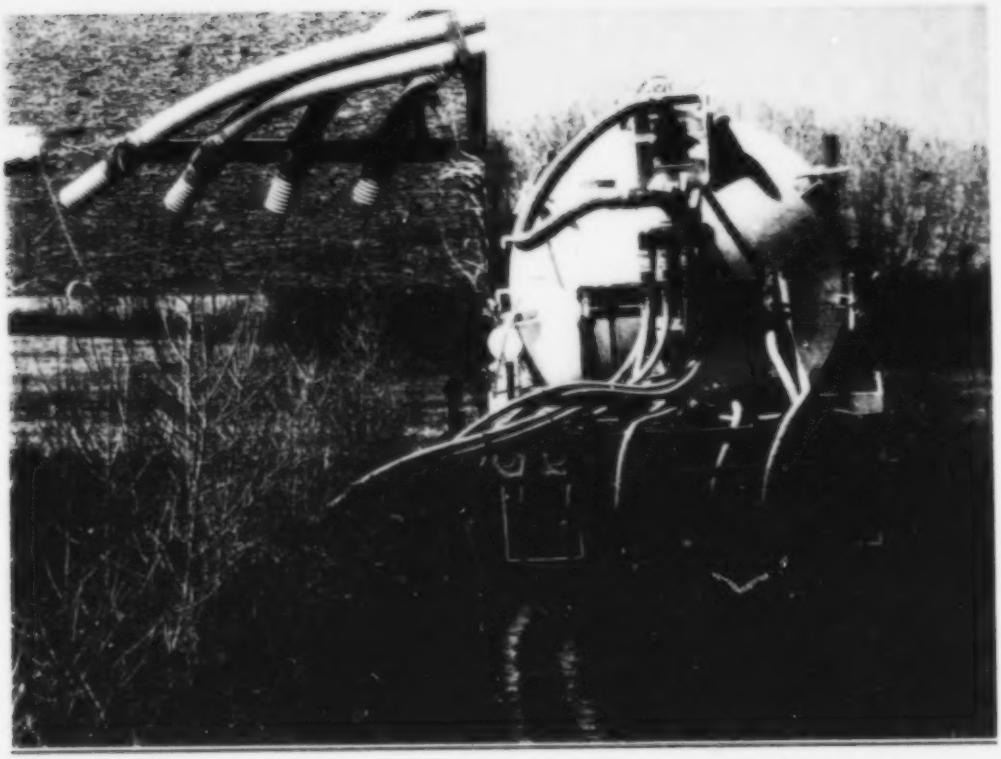


Figure 2. PAMI manure truck's tool bar and boom hose system applying swine effluent at the Preeceville site. Inset: Close-up of the delivery system.

2.1.3 Effluent application

On May 18, 2004, and again on May 11, 2005, PAMI surface-applied swine effluent at the Preeceville site. Swine effluent was taken from the lagoon at the nearby barns using the PAMI truck. Effluent was applied at pre-determined volumes and samples taken from the effluent were sent for analysis with the amount of nitrogen applied per hectare calculated afterwards. These rates are shown in Table 1. In 2004, the actual nitrogen applied was less than expected because the nitrogen concentration in the effluents was unusually low. The 22,500 and 45,000 l/ha rates were each applied in a single pass but the 90,000 l/ha treatment was applied in two passes to avoid runoff.

Table 1. Effluent application rates at Preeceville in 2004 and 2005

Rate		Nitrogen (kg/ha)	
(l/ha)	(gal/acre)	2004	2005
0	0	0	0
22,500	2,000	12	45
45,000	4,000	24	90
90,000	8,000	47	180

2.1.4 Data collection

Tree height and diameter at breast height (DBH) were measured before and after the effluent application in 2004 and 2005. Soil samples were taken before and after effluent application to monitor soil nitrogen. Soil was sampled at two depths (0-30 cm and 30-60 cm) and was taken from each plot at two points and bulked into one sample for each depth. Leaf samples were taken for total nitrogen analysis in August of 2004 and 2005 by collecting the 6th leaf from the end of the main shoot from each of six trees in each plot. The leaf samples were bulked by plot and then dried, ground and analyzed for total nitrogen.

2.1.5 Site maintenance

Maintenance included a combination of mechanical and herbicide control. Weeds were initially controlled through tillage and mowing but as the trees matured, chemical treatment became the preferred option to avoid damage to tree roots. Glyphosate was applied with a shielded sprayer, when needed, to give good weed control. In the fall, linuron was applied to the shelterbelts to reduce spring weed germination.

Figure 3. Left - Site maintenance using the shielded sprayer. Right - Effect of linuron application on weeds with the tree rows.

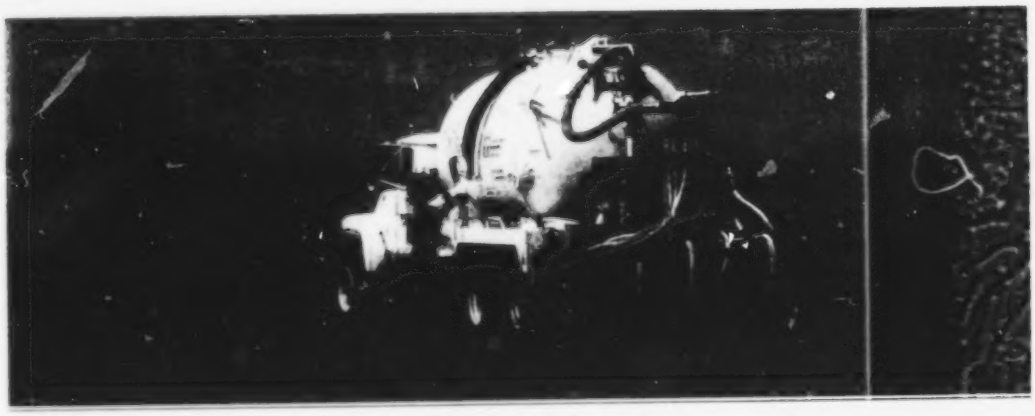


Figure 4 Application of swine effluent at the Preeceville site

2.2 Results

Soil nitrogen:

Soil nitrogen varied from sampling time to sampling time (Figures 5, 6). Although the nitrogen in the applied effluent was in the form of ammonium (NH_4), it was rapidly nitrified (converted to nitrate (NO_3)), since little ammonium was found in the soil, even if the soil was sampled soon after the effluent was applied (Figure 6). The soil nitrate levels in the 0-30 cm depth increased after application in May, 2004 but decreased again by fall (Figure 5a). Soil nitrate levels were related to the rate of effluent added. There was no difference in soil nitrogen levels in relation to the poplar clone treatment.

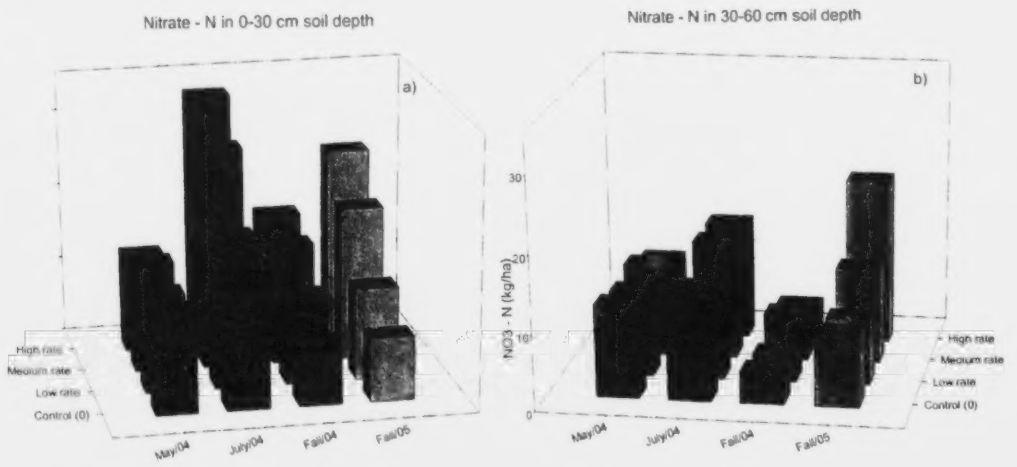


Figure 5. Nitrate nitrogen in soil before and after effluent application.

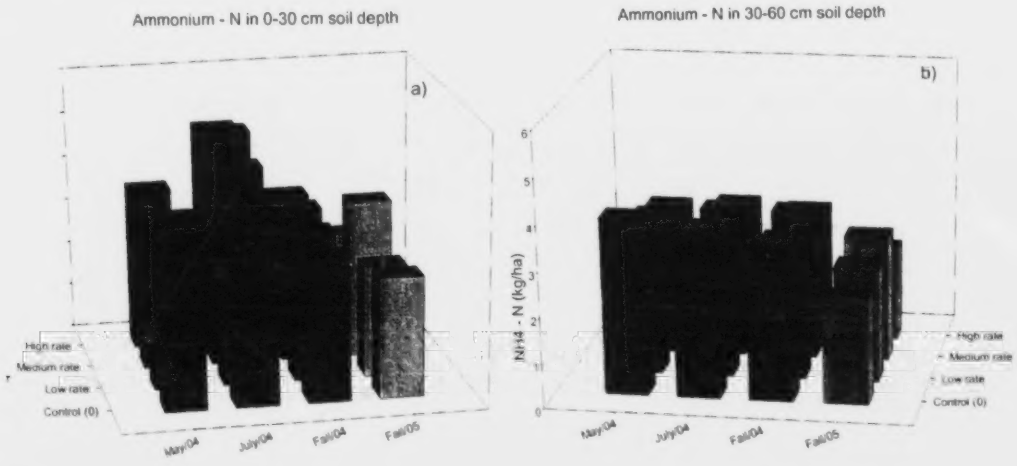


Figure 6. Ammonium nitrogen in soil before and after effluent application.

Tree growth:

By the fall of 2005, effluent application rates had no discernable effects on the growth of the poplar trees. The average tree heights at that time, for the different rates, varied from 261 to 275 cm, while a difference of over 20 cm would have been needed to show significant differences at the 5% level. Similarly for stem diameter at breast height (DBH), the averages varied from 21 to 24 mm while a difference of at least 4 mm would have been needed to show significant differences at the 5% level.

By the fall of 2005, the height of the Katepwa and Walker poplar was greater than for Hill and Canam poplar (Table 2). They also showed annual height increments greater than Hill and Canam. The pattern for DBH was the same, although the Katepwa and Hill were not significantly different from each other. For all measurements, however, Walker grew significantly faster than Canam poplar over the study.

Table 2. 2004 and 2005 height and diameter growth and final height and diameter of four hybrid poplar clones. Within any column, different letters after the numbers indicate that the clones are significantly different at the 5% level.

	Height (cm)			Diameter (mm)	
	Increment		Final	Increment	Final
Clone	2004	2005	2005	2005	2005
Walker	81 a	105 a	308 a	16.7 a	29.1 a
Katepwa	74 b	104 a	274 b	13.6 b	24.8 b
Hill	52 c	90 b	246 c	12.5 b	21.5 b
Canam	55 c	75 c	222 d	8.3 c	13.8 c
Average	66	93	263	12.8	22.3

The ratio of height growth to DBH growth was highest in the Canam poplar, indicating that these trees were more spindly than the other clones. Although biomass was not directly measured since this would have involved destructive sampling, aboveground biomass is generally a function of a tree's stem cross-sectional area and its height. From these values, it was estimated that the Katepwa poplar had an average of about 70% of the biomass of Walker poplar while Canam was estimated at only 20% of the Walker poplar's biomass. Even for the Walker poplar, the aboveground dry biomass was not estimated at higher than 2 kg. Hill poplar was notable for its branchiness (Figure 7) which could represent a substantial amount of biomass so, although its height and diameter were less than Walker and Katepwa, its biomass by 2005 was likely similar to that of the Katepwa poplar.

Figure 7. Summer, 2005 - Katepwa and Hill poplar at Preeceville

Leaf nitrogen:

There was no apparent effect of the effluent application rate on the leaf nitrogen content of the poplar trees. However, there were significant clonal differences since the leaves of Canam poplar consistently had higher leaf nitrogen across treatments and in both 2004 and 2005 (Table 3). The average nitrogen concentration in the Canam poplar leaf tissue was 7% greater than Katepwa, the clone with the lowest nitrogen.

Table 3. Percent nitrogen in the leaves of four poplar clones at Preeceville. In the "Average" column, different letters after the numbers indicate that the clones are significantly different at the 5% level.

	Nitrogen (% of leaf dry weight)		
Clone	2004	2005	Average
Canam	3.56	3.08	3.32a
Hill	3.41	3.06	3.24b
Walker	3.41	3.02	3.22b
Katepwa	3.21	2.98	3.10c
Average	3.40	3.04	3.22

2.3 Discussion

The Preeceville site was planted in 2002 so the trees, by the fall of 2005, had only four growing seasons. By that time, they had achieved an average height of 2.6 m and an average diameter of 2.2 cm. Although the trees are now well-established, their total biomass accumulation aboveground was estimated at less than 2 kg (dry weight) per tree so that they were not yet taking up large amounts of nitrogen. The available soil nitrogen before the first effluent application was an average of 13.2 kg/ha in the top 30 cm of the soil so that there was sufficient nutrient for normal growth of the trees. Consequently, the application of effluent did not significantly increase the growth of any of the four clones that had been planted.

The suitability of different poplar clones did differ however, since the Walker poplar was the fastest-growing over the period of this project, while the Canam poplar grew significantly slower and the Katepwa and Hill poplars were intermediate. The branchy Hill poplar had a substantially different form than the upright Walker and Katepwa poplar and could, in future years, increase in biomass more quickly since it appeared to be producing a large leaf area by 2005 (Figure 7).

Although there was no apparent growth response by any of the poplar clones to effluent application, the possibility was investigated that greater leaf nitrogen concentrations could indicate increased nitrogen uptake for higher application rates. This was not shown, however, since there was no effect of the rate of effluent applied on the nitrogen contained in the leaves of any of the four clones. The Canam poplar did prove to have a greater nitrogen concentration in the leaves than the other clones. But it was also the slowest-growing clone so that the higher nitrogen concentration may imply a greater rate of photosynthesis from a smaller leaf area. If a smaller leaf area implies reduced water use, this could mean that Canam has higher water use efficiency. Canam poplar was selected as a superior performer on dry sites so this may reflect its better drought adaptation even though it has no growth advantages when water and nitrogen are not limiting.

The design of the planting was successful in allowing for the application of swine effluent with the PAMI manure tanker truck. The compatibility of this type of agroforestry design for effluent application will, however, depend on the method of application. Although the tree rows were spaced widely enough to allow for tractor access, trailing hose application systems may not work unless there is sufficient space for the hose to clear the tree rows before the tractor begins on a new row.

The modifications by PAMI to the delivery system of the effluent tanker truck successfully allowed for the even application of effluent across the root zone of the trees with an offset boom equipped with an end nozzle that delivered effluent as far as the base of the trees. The main boom of the truck was a 3 m wide tool bar to which an adjustable boom with adjustable nozzles was added for broadcasting the effluent. The boom and nozzles were arranged so that effluent could be applied 1.5 m to the side of the truck width. Manure was broadcast along 3 m of the total boom (i.e. 1.5 m of the original boom and the 1.5 m extension). Nozzles were spaced at 30 cm along this boom for even application. By this method and by adjusting the truck speed appropriately, it was possible to surface-apply the effluent evenly without runoff with a single pass for the two lower application rates and with two passes at 45,000 l/ha each for the high rate of 90,000 l/ha.

The effluent was surface-applied because it is known that poplar roots are very shallow and would be damaged by incorporation, especially while the trees were young and in their establishment period. In future, the need to incorporate the effluent may outweigh the concern for the roots and older trees may be able to compensate for damaged shallow roots by developing deeper roots.

The landowner's goals for the establishment of a healthy poplar planting were met. The future use of this planting for the simultaneous provision of shelter for herbaceous crops and wood production in the poplar trees will be monitored in cooperation with the landowner.

Although nitrogen uptake rates were not shown in this young planting, the parallel use of older trees at the Henribourg block planting provided a point of comparison.

3 Henribourg

3.1 Materials and Methods

3.1.1 Site

This site located at the Weyerhaeuser Seed Orchard at Henribourg, SK was initially established in 1998 under the Canada-Saskatchewan Agri-Food Innovation Fund with the partnership of Weyerhaeuser Canada and SaskPower. Its purpose was to examine spacing, growth and yield and clonal differences of various hybrid poplar clones. For this study, 384 Walker poplars were selected (Figure 8) to be tested under 4 different fertilization regimes.

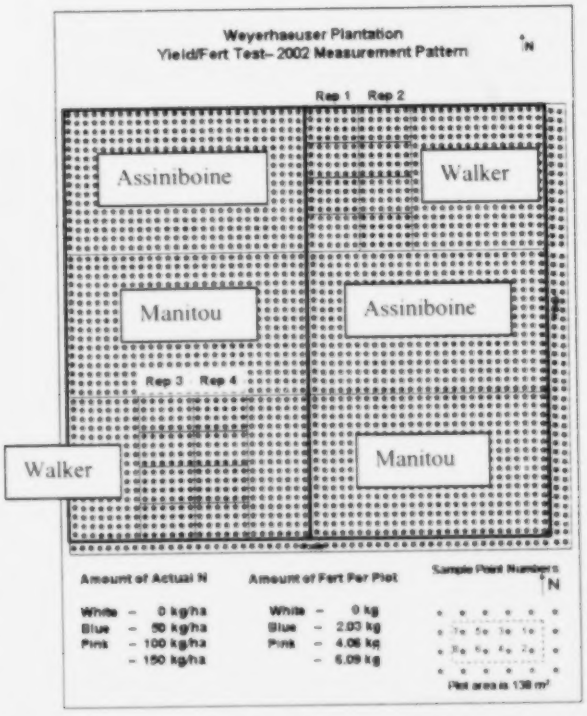


Figure 8. Nitrogen fertilization treatments for Walker poplar block plantation at the Weyerhaeuser Seed Orchard, Henribourg, SK (105°35 °26

Figure 9. Fall, 2003. 6-year-old hybrid poplar trees at Henribourg

3.1.2 Nitrogen application

Granular nitrogen, applied as ammonium nitrate (33-0-0), was applied at four different rates (0, 50, 100,150 kg/ha) to the selected Walker poplar at the site (Figure 8). The fertilizer was applied using hand spreaders in which the granules were applied by making several passes over the plots. The same rates were applied in 2001, 2003 and 2004.

3.1.3 Data collection

Measurements included the total height and the height increase of the trees, and the ratio of the height increment to total tree height (expressed as percent) and the diameter at breast height (DBH). Only the centre eight trees of each plot were measured. Soil samples were taken before application and each fall after the growing season was complete. Soil at two depths 0-30 cm and 30-60 cm was taken from the centre row of each plot at 3 points and bulked into one sample for each depth. Leaf samples were taken each year in August collecting the 6^{th} and 12^{th} leaf from each of the eight measured trees. The leaf samples were bulked by plot and leaf number. Both the soil and leaf samples were dried, ground and sent to a laboratory for nitrogen analysis.

3.2 Results

Soil Nitrogen:

The fertilizer that was applied in 2001, 2003 and 2004 as broadcast granular ammonium nitrate (33-0-0) increased the soil nitrogen levels in subsequent soil samplings (Figures 10, 11). In the fall of 2003, much of the nitrogen that had been applied was still present in the top 60 cm of the soil. In the fall of 2004, a dry year, however, despite the application of the same amount of nitrogen, soil nitrogen levels were much lower than in the previous fall. No fertilizer had been applied in 2005 and, by the fall of 2005, soil nitrogen levels were similar to those measured before the 2003 fertilizer application.

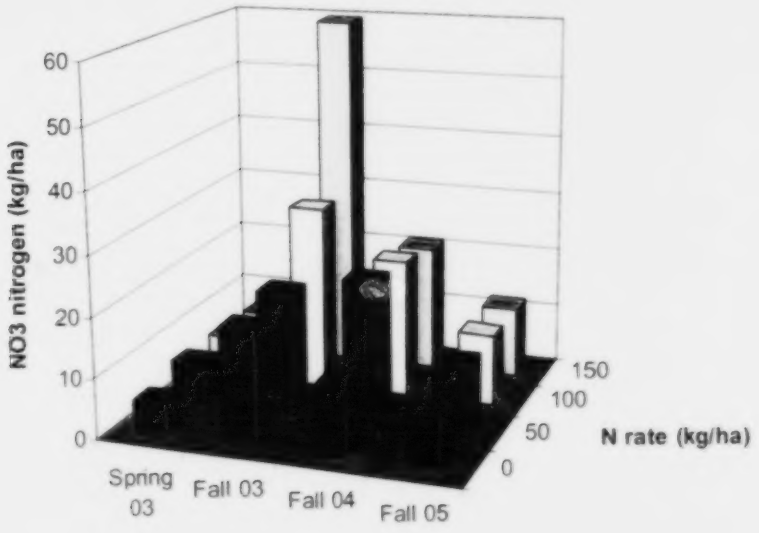


Figure 10. Measured soil nitrogen before and after fertilizer application at 0-30 cm soil depth. Fertilizer application occurred in the spring of 2003 and 2004.

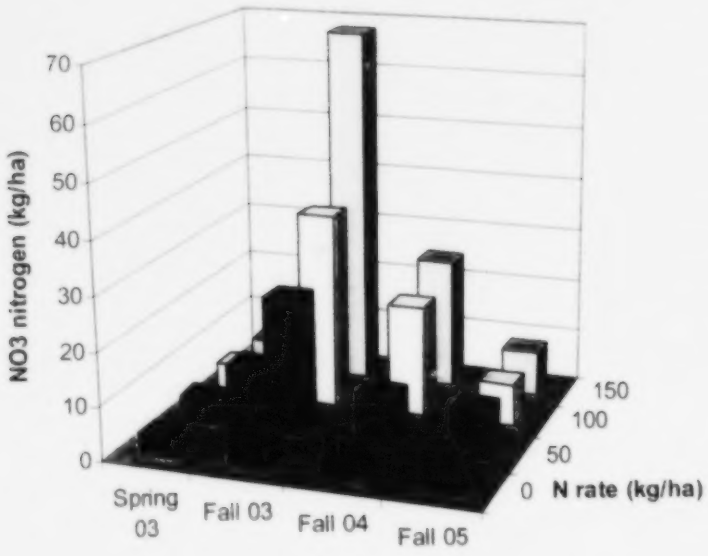


Figure 11. Measured soil nitrogen before and after fertilizer application at 30-60 cm soil depth. Fertilizer application occurred in the spring of 2003 and 2004.

Plant response:

In the 2001-2005 growing seasons, there was no significant height growth response of the Walker poplar to added nitrogen (Table 4) whether height increase was expressed as actual values (m) or relative values (%). The final height in the fall of 2005 was an average of 7.4 m (Table 4) and the DBH average was 8.7 cm (Table 5). Neither growth indicator showed a significant response to the fertilizer application rate although the highest two rates had a greater average DBH (9.1 cm) compared to the low and zero rate average (8.1 cm) (Table 5).

The overall average height of the Walker poplar showed a general trend of top dieback from one year to the next as seen by the downturns in the lines in Figure 12. The new growth for each year was always measured as the difference between the final fall height and the height at which the season's new growth began – the bud scar at the base of the primary new shoot. The new growth often began at a height less than the previous fall's final height. When only the length of the annual new growth was considered for 2003-2005, there did appear to be an increase in response to the rate of nitrogen fertilizer applied (Figure 13) even though there was no effect in the final tree height.

Table 4 Growth data at Henribourg site (Weyerhaeuser)

Height increase (m) (ie. New growth - 2001)

N Rate (kg/ha)	Rep1	Rep2	Rep3	Rep4	Average
0	1.92	1.68	1.55	1.33	1.62
50	1.56	1.61	1.28	1.34	1.45
100	1.64	1.50	1.50	1.26	1.48
150	1.66	1.97	1.61	1.44	1.67

2001 Height increase (%)

N Rate (kg/ha)	Rep1	Rep2	Rep3	Rep4	Average
0	58.0	47.8	63.7	49.9	54.8
50	59.7	46.3	54.7	56.3	54.2
100	49.7	42.9	68.4	49.1	52.5
150	49.9	58.0	57.0	57.5	55.6

Height increase (m) (ie. New growth - 2002)

N Rate (kg/ha)	Rep1	Rep2	Rep3	Rep4	Average
0	1.58	1.45	1.65	1.14	1.45
50	1.24	1.23	1.31	1.67	1.36
100	1.67	0.97	1.55	1.60	1.45
150	1.46	1.18	1.53	1.68	1.46

2002 Height increase (%)

N Rate (kg/ha)	Rep1	Rep2	Rep3	Rep4	Average
0	29.7	27.9	42.0	28.4	32.0
50	30.7	24.7	36.9	45.6	34.5
100	33.8	19.4	41.3	43.0	34.4
150	29.3	22.1	34.9	42.7	32.3

Height increase (m) (ie. New growth - 2003)

N Rate (kg/ha)	Rep1	Rep2	Rep3	Rep4	Average
0	0.96	1.09	1.24	1.17	1.11
50	1.23	1.12	1.52	1.40	1.32
100	1.29	1.56	1.67	1.84	1.59
150	1.11	1.40	1.92	1.61	1.51

2003 Height increase (%)

N Rate (kg/ha)	Rep1	Rep2	Rep3	Rep4	Average
0	16.2	17.0	26.4	24.1	20.9
50	21.0	22.5	33.2	32.4	27.3
100	23.2	26.9	37.4	43.9	32.8
150	18.1	24.7	46.2	33.5	30.6

Height increase (m) (ie. New growth - 2004)

N Rate (kg/ha)	Rep1	Rep2	Rep3	Rep4	Average
0	0.41	0.40	0.81	0.51	0.53
50	0.63	0.39	1.17	0.42	0.65
100	0.17	0.60	0.43	0.38	0.39
150	0.50	0.71	0.87	0.76	0.71

2004 Height increase (%)

N Rate (kg/ha)	Rep1	Rep2	Rep3	Rep4	Average
0	6.0	5.3	13.5	8.5	8.3
50	8.9	6.4	19.1	7.3	10.4
100	2.4	8.6	7.2	5.9	6.0
150	7.4	9.6	14.2	12.6	11.0

Height increase (m) (ie. New growth – 2005)

N Rate (kg/ha)	Rep1	Rep2	Rep3	Rep4	Average
0	1.19	0.76	0.56	0.50	0.76
50	0.76	0.74	0.60	0.73	0.71
100	0.81	0.96	0.66	0.55	0.74
150	0.88	0.90	0.90	0.77	0.80

Fall, 2005 Final Height (m)

N Rate (kg/ha)	Rep1	Rep2	Rep3	Rep4	Average (non-sign.)
0	8.1	8.2	6.9	6.7	7.5
50	8.0	7.0	7.2	6.1	7.1
100	7.5	8.1	6.8	7.0	7.3
150	7.8	8.8	7.3	7.2	7.8

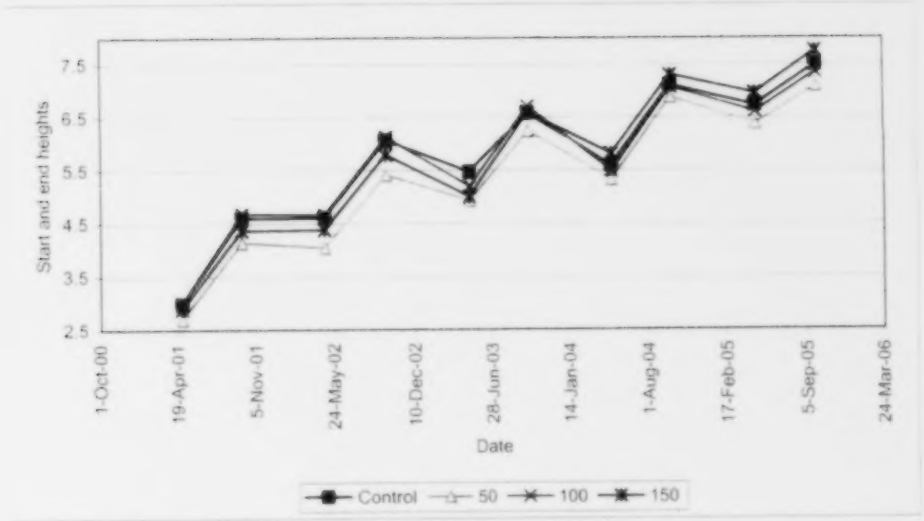


Figure 12. Height increase of Walker poplar (2001-2005)

Table 5. Effect of fertilization on diameter at breast height (DBH) of Walker poplar

	Diameter increase (cm) (ie. New growth – 2005)					2005 DBH (cm)				
N Rate (kg/ha)	Rep1	Rep2	Rep3	Rep4	Average	N Rate (kg/ha)	Rep1	Rep2	Rep3	Rep4	Average (non-sign.)
0	1.3	1.7	1.1	0.4	1.1	0	9.8	10.5	7.6	7.1	8.7
50	1.5	1.8	0.6	0.8	1.2	50	9.1	7.1	7.1	6.8	7.5
100	2.0	1.3	0.5	1.1	1.2	100	10.3	10.3	7.4	9.3	9.3
150	2.0	3.2	1.0	2.1	2.1	150	9.1	11.2	7.7	8.4	9.1

Leaves collected in 2003 from rapidly-growing shoots from the top whorl of branches at the top of the trees showed that total nitrogen content of the leaves was increased by fertilization and that there was a linear relationship between leaf total nitrogen content and the growth of the terminal shoot in 2003 (Figure 14) although leaf nitrogen did not vary significantly from treatment to treatment.

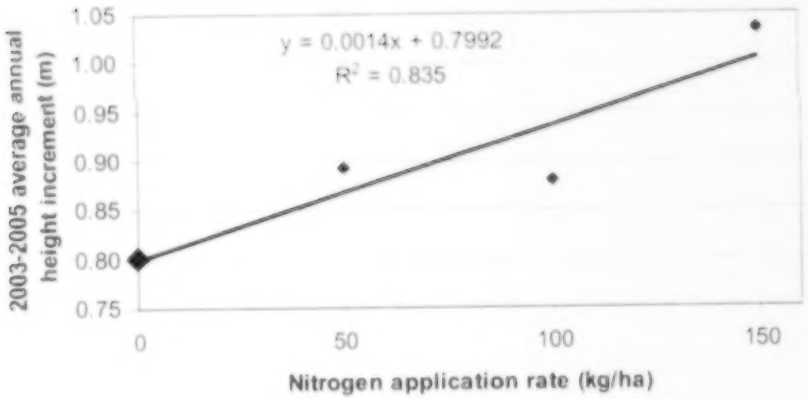


Figure 13. The height increments of the main shoots of Walker poplar in response to added nitrogen fertilizer. The annual shoot increments for the years 2003, 2004 and 2005 were averaged.

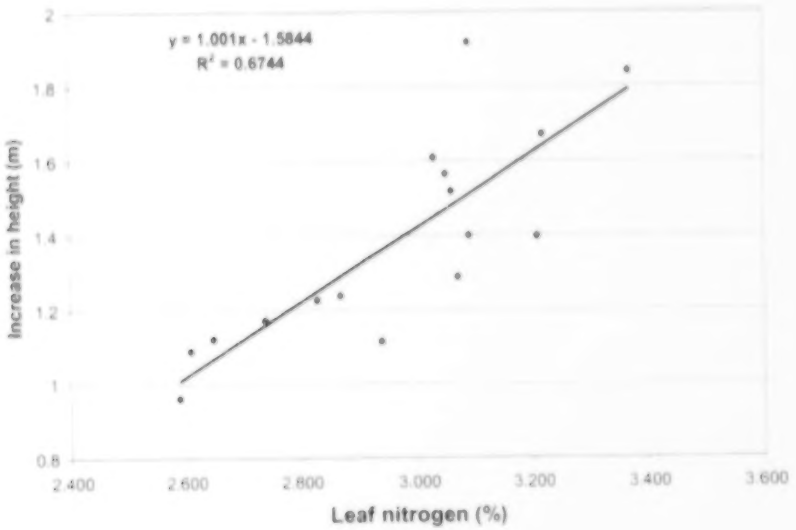


Figure 14. Correlation of leaf nitrogen in the 6th leaf with the height growth of the terminal shoot in Walker poplar trees at the Weyerhaeuser site in Henribourg (2003 results).

3.3 Discussion

The Walker poplar trees which had been planted at Henribourg in 1998 achieved an average height of 7.4 m and an average DBH of 8.7 cm by the fall of 2005 (i.e. after eight growing seasons). Available soil nitrogen prior to fertilization was less than 10 kg/ha before fertilizer was applied in the spring of 2003 and fertilizer application increased the

available soil nitrogen in both 2003 and 2004. By the fall of 2003, most of the nitrogen that had been applied was present as increased soil nitrogen. The soil nitrogen by the fall of 2004, a dry year, was not as high as in the previous year. The fate of the nitrogen must have been a combination of uptake by the trees and losses through denitrification or leaching. Since the nitrogen levels at the 30-60 cm depth were equal to those in the top 30 cm, it is possible that some leaching was occurring but most of the unaccounted-for nitrogen occurred in 2004, a dry year in which less leaching should have occurred than in 2003.

The trees were not shown to increase their rate of nitrogen uptake in response to added nitrogen rates since the increased nitrogen availability did not result in overall growth increases as determined by the final height and DBH of trees treated at different nitrogen application rates. When only the annual new growth was considered and combined for the 2003, 2004 and 2005 growing seasons, it appeared that the new growth was increased by nitrogen application (Figure 13) but, perhaps because of annual dieback or plot-to-plot variability, this was not reflected in overall tree height by the fall of 2005 (Table 4).

Some leaves in these Walker poplar plots had greater nitrogen concentrations than others and higher nitrogen levels were correlated to the length of the new growth (Figure 14). According to Shinano et al. (2001), young trees of a hybrid poplar (*P. Xeuramericana*) clone typically had a leaf nitrogen concentration of 3.4% to 4.1% and, at the Preeceville site, the younger trees including the Walker and especially, the Canam poplars, had higher leaf nitrogen concentrations than the 2.6% to 3.4% levels in Walker poplar leaves found in this study. This suggests that nitrogen uptake in some of the plots was limited, perhaps related to the age of the trees or the site. Since the availability of nitrogen did not seem to be the key factor, it is supposed that other factors such as variability in soil texture, moisture or salinity were responsible for the differences in plot-to-plot leaf nitrogen concentrations and growth differences.

Although the Walker poplar trees at this site have achieved complete crown closure in most plots, nitrogen apparently did not limit tree growth so the application of extra nitrogen did not appear to be required by the trees at this age. Recycling of nitrogen through leaf litter drop or reallocation within the trees may also mean that limitations to available soil nitrogen may not have immediate effects on tree growth. Since these trees are still relatively young at eight years of age, it may be that nitrogen limitations may become apparent as the trees grow to a greater age and size so that further fertilizer application at a future date may be needed.

4 Conclusions

Planting design:

A poplar planting was successfully established at Preeceville in an alley-cropping configuration, to which swine effluent was surface-applied using modifications to the boom of the Prairie Agricultural Machinery Institute's (PAMI) tanker truck. The tree configuration was suitable for this technique of application but other application methods could require design modifications to the tree planting design.

The poplar planting at the Weyerhaeuser Seed Orchard at Henribourg was planted in 1998 in a block plantation design with a spacing of 2.4 m X 2.4 m. Although this may be suitable for wood production, it is not compatible with most swine effluent application systems used today. It could be suitable for effluent application through solid set irrigation systems, hoses or other options which do not require access by machinery.

Soil nitrogen and growth response to added nitrogen:

Soil nitrogen in both sites increased because of the added nutrients, whether as effluent or as granular fertilizer. Despite the apparent lack of response by the trees, the soil nitrogen contents decreased after application, suggesting a combination of gaseous losses (denitrification) and leaching. Leaching was not likely a major factor at Preeceville since the nitrogen content in the lower soil layer was always less than in the upper layer. At Henribourg, the nitrogen content in the lower levels was similar to the shallower depth but leaching was not likely a major factor there since most of the unaccounted-for nitrogen was in 2004, a dry year. Ammonium levels decreased rapidly after effluent application while nitrate levels increased.

The young poplar trees at Preeceville did not respond to the addition of swine effluent in their third and fourth growing seasons, likely because their nitrogen requirements were small at that age and the nitrogen levels in the soil were adequate for their needs. At Henribourg, although the trees were older and therefore had greater nitrogen needs, and although the soil nitrogen was less than at Preeceville, no growth response to added ammonium nitrate fertilizer was measured. From these two studies, it appeared that nitrogen needs by the young poplar trees were not very high. Recommendations for fertilization of poplar plantations in Washington and Oregon therefore appear to be higher than what is needed for satisfactory growth in Saskatchewan.

In the Henribourg trees, leaf nitrogen concentrations varied within the leaves of Walker poplar but all leaf levels were above 2.5%. The concentration was shown to relate to elongation of the terminal shoot in a growing year. This would suggest that leaf nitrogen levels should be 3% or more for good tree growth. Stanturf *et al.* 2001 said that poplar leaf nitrogen levels needed to be maintained above 2% but that, when leaf levels were kept above 2.5%, the effect of further fertilization on overall growth and yield would be uncertain. In this study, since the leaf nitrogen levels were not well-related to the soil

nitrogen level, it appeared that tree growth was more strongly affected by other soil characteristics.

According to Schroeder (1999), some soils are suitable for poplar growth while others provide growth limitations. Poplar trees generally did not grow well on clays or sandy soils while a soil pH of between 5.0 and 8.0 was needed for reasonably good tree growth. Although climate, particularly the moisture deficit, was an over-riding factor for site suitability, salinity, slope and depth of A-horizon were also important factors. Both the Preeceville and Henribourg sites had variable soils, with knolls and low spots and variable depths of the A-horizon and some areas of apparent salinity so these factors likely contributed to the variability of the poplar growth.

Clonal Differences:

Differences in clonal growth were significant at the Preeceville site with Walker being the best performer over the four-year period and Canam being the poorest performer. The other clones, Katepwa and Hill also performed well on the site and this site will be of continuing interest in monitoring clonal performance and nitrogen response. Although the first four years' growth was greater for Walker and Katepwa poplar than for Hill poplar, Hill was very bushy and had a great deal of foliage so that it may have greater biomass accumulation in the future.

Other Consideration:

The use of hybrid poplar in effluent application systems may be most practical if the value of the poplar as an alternative crop is taken into account. The operations of establishing and harvesting a hybrid poplar plantation can be done with conventional farm equipment. Hybrid poplar has been shown to be suitable for pulp, orientated strand board (OSB) and other wood products.

Protection of herbaceous crops in an alley-cropping system would also be expected to result in greater crop yields. Other benefits of the poplar trees such as the sequestration of carbon and the protection of biodiversity may also contribute to the system's value.

The economic and environmental considerations of poplar shelterbelts in an alley-cropping configuration may make it an attractive option. The poplar trees are expected to increase in their need for nitrogen as they become larger but further research on the nitrogen needs of different hybrid poplar clones under Saskatchewan conditions will be required before fertilization recommendations can be made.

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6 Appendix: Project Photos

Figure 15. Mid-summer, 2004 – The Preeceville alley-cropping system

Figure 16. 2-year-old poplar shelterbelts at Preeceville

Figure 17. Swine barn across road from Preeceville planting

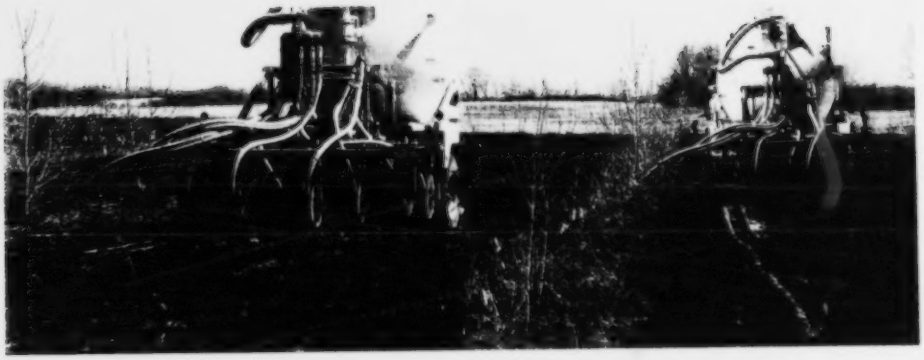

Figure 18. Spring, 2004 – Swine effluent application at Preeceville

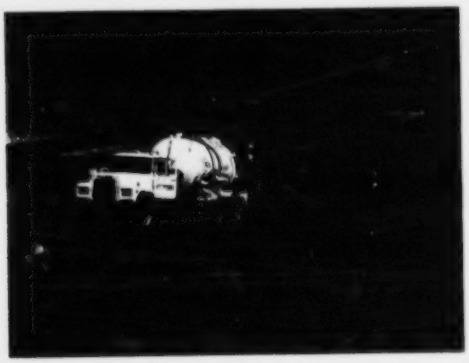

Figure 19. May, 2004 – Filling the tank at Preeceville